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(54) Ink jet print head declogging method and apparatus

(57) An ink jet printer includes a piezoelectric print head adapted to eject ink in response to the application of a voltage pulse to a piezoelectric element in the print head. A signal generator produces a printing voltage pulse of a first magnitude for ejecting a printing drop of ink from the print head, and an unclogging voltage pulse of a second magnitude greater than the first for unclogging the print head. A controller selectively applies the printing voltage pulse or the unclogging voltage pulse to the print head.

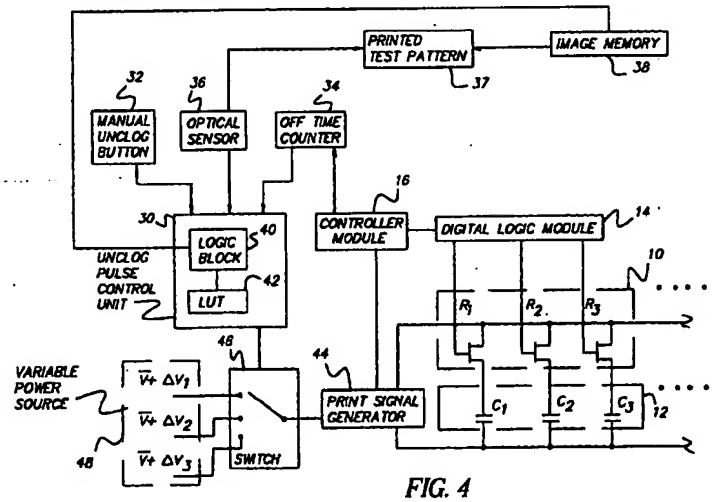

FIG. 4

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Description

[0001] The present invention relates generally to ink jet printing apparatus and, in particular to an ink jet printer having a piezoelectrically actuated print head with means for unclogging the print head.

[0002] In a drop on demand ink jet printer, if the time between ink ejections from the nozzles is long compared to ink liquid carrier evaporation time, the ink starts to solidify. This clogs the nozzles and prevents the proper amount of ink from being ejected from those nozzles. Additionally, a small solid particle such as a dirt particle may cause a nozzle to be clogged. In this case the print head may be moved to a cleaning station, and the orifice plate is cleaned or vacuumed to unclog the nozzles. The print head may also be removed and cleaned manually.

[0003] Several techniques are proposed in prior art to clear the ink clog in a nozzle or to decrease the possibility of clogging in the nozzles. U. S. Patent No. 4,540,997, issued September 10, 1985 to Biggs et al., entitled "Method and Apparatus for Avoiding the Drying of Ink in the Ink Jets of Ink Jet Printers" discloses an ink jet printer which prevents clogging of the nozzles by insuring that the drops are fired from nozzles in set periods of time. The Siliconics model 30790-02 ink jet printer, during normal printing, utilizes a microprocessor to monitor the number of drops each ink channel ejects. If a channel has not been used within a 100 second period, the microprocessor commands the channels to eject a drop of ink. U. S. Patent No. 3,925,789, issued December 9, 1975 to Kashio, entitled "Ink Jet Recording Apparatus" discloses an ink jet printer wherein, during normal printing a timer is employed to count the elapsed time between ink ejections from each of the ink nozzles. Then, if elapsed time between ejections for any nozzle exceeds a preselected time, the control unit is triggered which in turn activates a pump which ejects ink from the unused nozzle. In addition, this patent discloses the ejection of ink from each nozzle for several seconds after the printer is turned on. U. S. Patent No. 4,577,203, issued March 18, 1986 to Kawamura, entitled "Ink Jet Recording Apparatus" discloses an ink jet recording apparatus in which the ink channels can be disconnected from the ink reservoir,. During this time a suction mechanism is used to clear the nozzles. U. S. Patent No. 5,619,232, issued April 8, 1997 to Maeno, entitled "Maintenance Station of Ink Jet Printer and Cap and Pump Included Therein" discloses a maintenance station for an ink jet printer which uses the same method of suction to clear the clogged nozzles. U. S. Patent No. 4,806,955, issued February 21, 1989 to Koto et al., entitled "Ink Jet Printer of the Ink-On-Demand Type" discloses an ink jet printer in which a cap covers the nozzles and a pump ejects ink through the nozzles, to avoid ink from clogging the nozzles.

[0004] An alternative method used in some ink jet printers is washing the nozzles after a selected number of pages are printed. In these methods the nozzles are transported to a washing station where they are washed or wiped using different means.

[0005] The above discussed methods provide ways of preventing clogs from forming in nozzles, or provide ways of removing clogs from nozzles. All of the above methods include some shortcomings. In the case of washing the nozzles to remove ink, it can damage the orifice plate. Use of suction cups and vacuum or pressure pumps can add to the complexity of and hence the cost of a printer apparatus. Firing drops at timed intervals to prevent clogs requires timing circuitry, and is wasteful of ink. There is a need therefore for an improved declogging mechanism which can provide nozzle declogging and print head priming feature without a large added cost.

[0006] The need is met according to the present invention by providing an ink jet printer having a piezoelectric print head adapted to eject ink in response to the application of a voltage pulse to a piezoelectric element in the print head. A signal generator produces a printing voltage pulse of a first magnitude for ejecting a printing drop of ink from the print head, and an unclogging voltage pulse of a second magnitude greater than the first for unclogging the print head. A controller selectively applies the printing voltage pulse or the unclogging voltage pulse to the print head.

Fig. 1 is a schematic diagram useful in describing the driving circuitry for a prior art piezoelectric ink jet print head;

Fig. 2 is a waveform diagram illustrating prior art ink jet drive signals generated by the driving circuit shown in Fig. 1;

Fig. 3 is a waveform diagram illustrating the jet unclogging drive signals according to the present invention;

Fig. 4 is a schematic diagram of one embodiment of a drive circuit for a piezoelectric ink jet print head according to the present invention;

Fig. 5 is an illustration of a test pattern employed in one mode of practicing the present invention;

Fig. 6 is a schematic diagram of an alternative embodiment of a drive circuit according to the present invention; and

Figs. 7 is a waveform diagram illustrating an alternative pulse shape employed with the present invention.

[0007] A piezoelectric print head used for drop on demand printing, uses a piezoelectric element located in the print head to create a pressure wave or volume displacement to expel a drop of ink from an orifice in the print head. The piezoelectric element is driven by a voltage pulse waveform having a magnitude V. The voltage V is fairly small, in the range of 10 - 100 volts. According to the present invention, if a larger voltage (V + ΔV volts), which is larger than the printing voltage, but

smaller than a limit voltage V_{stress} (above which the piezoelectric element is damaged or stressed) or the voltage V_{ingest} (above which air may be ingested into the print head on the fill portion of the print cycle), is applied to the piezoelectric element, it can create a larger pressure wave that can declog the nozzles in the print head.

[0008] Fig. 1 shows a general structure for an array of piezoelectric elements and drivers as is found in a piezoelectric print head. This structure is well known in prior art and is comprised of an array of switching transistors **10** connected to an array of capacitors **12** corresponding to piezoelectric elements.

[0009] Digital image data is input one line at a time into the digital logic module **14** which consists of shift registers and latches. The digital logic module clocks a line of digital print data into a set of shift registers. A controller module **16** sets the timing and synchronizes the functions of the printer. The print signal generator **18** provides voltage V from power source **20** to the switching transistor array **10** which apply a voltage to actuate the piezoelectric elements **12**, shown as an array of capacitors. Print signal generator **18** supplies the optimal shape signal to the piezoelectric elements for printing.

[0010] The device as described above is capable of producing a driving wave form as shown in Fig. 2. A print cycle **21** is comprised of a fill period **22** wherein a negative voltage is applied to a piezoelectric element **12**, causing the nozzle to fill with ink; a print period **23** wherein a positive voltage is applied to a piezoelectric element **12**, causing the nozzle to eject ink; and a rest period **24** where the voltage on the piezoelectric element is returned to zero prior to the nozzle being refilled with ink for a next print cycle. The wave form shown in Fig. 2 is merely an example of wave forms used in driving piezoelectric ink jet heads. The print cycle pulse can be designed to have different shapes, so as to achieve different functions. It can also have various voltage (V) magnitudes. The piezoelectric actuator typically has two electrodes attached to it, which receive the electrical signal which is convened to mechanical energy by the actuator. In the example under discussion, one electrode would be connected to ground, and one would receive the electrical signal shown in Fig. 2. The positive and negative voltage polarities are chosen such that a negative voltage causes a mechanical expansion of the chamber holding the ink, and a positive voltage causes a mechanical compression of the chamber holding the ink. When the voltage is constant, the chamber size is held constant. Thus, only the transitions of the voltage waveform are active in filling or firing ink. The first (downward) transition **25** of the waveform in Fig. 2 causes the chamber to fill with additional ink, and we refer to its magnitude as Vfill. The second (upward) transition **26** of the waveform causes the firing of a drop, and we refer to its magnitude as Vfire, or simply as V. The third (downward) transition **27** returns the chamber to its original size, and may be chosen so as to help cancel any remaining meniscus motion at outlet of the nozzle. We refer to it as Vcancel. These portions of the waveform may then be followed by a rest period Trest, after which the previously described print cycle may be executed again.

[0011] The method of operating a print head according to the present invention is described as follows. Referring to Fig. 3, an unclogging pulse **28** is generated in which the second (upward) transition **26** in the signal is not V but rather $V+\Delta V$, where $V+\Delta V$ is the unclogging voltage Vunclog. Referring to Fig. 4, an unclog pulse control unit **30** is capable of receiving an input signal from any one of several input sources, including a manual unclog button **32**, an off time counter **34** which monitors the elapsed time since the last previous print head actuation, and an optical sensor **36**, which detects clogged nozzles by the absence of printed dots in a printed test pattern **37**. The test pattern is stored in image memory **38** in the printer. An example of a test pattern **37** is shown in Fig. 5, indicating that some of the nozzles at locations indicated as **39** are clogged.

[0012] The unclogging pulse controller unit **30**, contains a logic unit **40** and a look up table (LUT) **42** based on the results of prior experiments, which enable it to choose an unclogging-pulse strength index n and an unclogging pulse shape index m, based on the elapsed time, optical error results, or operator input. The output of the unclog pulse controller unit **30** is supplied to the print signal generator **44** via a switch **46**. One of the output components is the strength index n which signals the switch **46** to supply any one of the several voltages available to the print signal generator **44** from variable power source **48**. This embodiment advantageously uses a print signal generator **44** to generate the unclog signal. This feature minimizes the costs of manufacturing and maintenance of the printing system of the present invention.

[0013] In an alternative embodiment as illustrated in Fig. 6, the outputs of the unclog pulse controller unit **30**, which are the shape index (m) and the strength index (n) are supplied to an unclog signal generator **50**, which is capable of producing any one of several pulse shapes particularly tailored to the unclogging function.

[0014] As illustrated in Fig. 3, the unclogging pulse shape may be chosen to be the same as the drop firing pulse shape, except that the magnitude V of the firing transition is chosen to be larger, by an amount specified by the strength index n. Alternatively, as shown in Fig. 7, the shape of the unclogging pulse may be chosen to be different, as specified by the shape index m. In the example shown, the slope of the canceling transition **27** (Vcancel) is chosen to be less, to minimize the probability of air ingestion into the nozzle.

[0015] It is important to note that the unclogging pulses are preferably applied to the print head when the print head is parked in a capping station, or cleaning station, or ink receiving station, and not during the action of printing a page, since the unclogging drops

produced may be quite larger than the normal printing drops, and may be noticeable, if deposited on a page. Thus, whether the unclogging signal is generated by operator intervention, or by an optical sensor, or by a timer, the print head is preferably moved to a specified unclogging station before unclogging pulses are applied.

[0016] In either embodiment it is important that the magnitude of the unclogging pulse (V+ΔV) be smaller than either of the two limit voltages mentioned above:

$$V + \Delta V < V_{stress}$$

$$V + \Delta V < V_{ingest}$$

[0017] Added voltages (ΔV) in the range of 10-20 volts, well below the limit voltages, have been found to be useful in unclogging clogged nozzles.

[0018] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

Claims

1. An ink jet printer, comprising:

   a) a piezoelectric print head adapted to eject ink in response to the application of a voltage pulse to a piezoelectric element in the print head;
   b) a signal generator for producing a printing voltage pulse of a first magnitude to the piezoelectric element for ejecting a printing drop of ink from the print head, and an unclogging voltage pulse of a second magnitude greater than the first for unclogging the print head; and
   c) a controller for selectively applying the printing voltage pulse or the unclogging voltage pulse to the print head.

2. The ink jet printer claimed in claim 1, wherein the controller further comprises:

   a) means for driving the print head to print a test pattern;
   b) an optical sensor for sensing the test pattern; and
   c) means responsive to the optical sensor for determining the presence of a clogged print head and causing the signal generator to apply the unclogging voltage pulse to the print head in response thereto.

3. The ink jet printer claimed in claim 1, wherein the controller further comprises:

   a) a manually operated switch for causing the signal generator to apply the unclogging voltage pulse to the print head.

4. The ink jet printer claimed in claim 1, wherein the controller further comprises:

   a) a timer for monitoring the elapsed time between application of voltage pulses to the print head; and
   b) means responsive to the elapsed time exceeding a predetermined limit for causing the signal generator to apply the unclogging voltage pulse to the print head.

5. The ink jet printer claimed in claim 1, further comprising means for causing the unclogging voltage to take one of a plurality of voltage levels or pulse shapes.

6. A method of driving a piezoelectric ink jet print head, comprising the steps of:

   a) applying a print voltage pulse of a first magnitude to a piezoelectric element in the print head to form a printing drop; and
   b) applying an unclogging voltage pulse of a second magnitude, higher than the first to the piezoelectric element for unclogging the print head.

7. The method claimed in claim 6, further comprising the step of monitoring the elapsed time between voltage pulses applied to the print head and applying the unclogging voltage pulse after a predetermined elapsed time.

8. The method claimed in claim 6, further comprising the steps of:

   a) printing a test pattern with the print head;
   b) observing the test pattern to detect a clog in the print head; and
   c) applying the unclogging voltage pulse to the print head in response to detecting a clog.

9. The method claimed in claim 6, wherein the unclogging voltage pulse can be any one of a plurality of magnitudes and shapes.

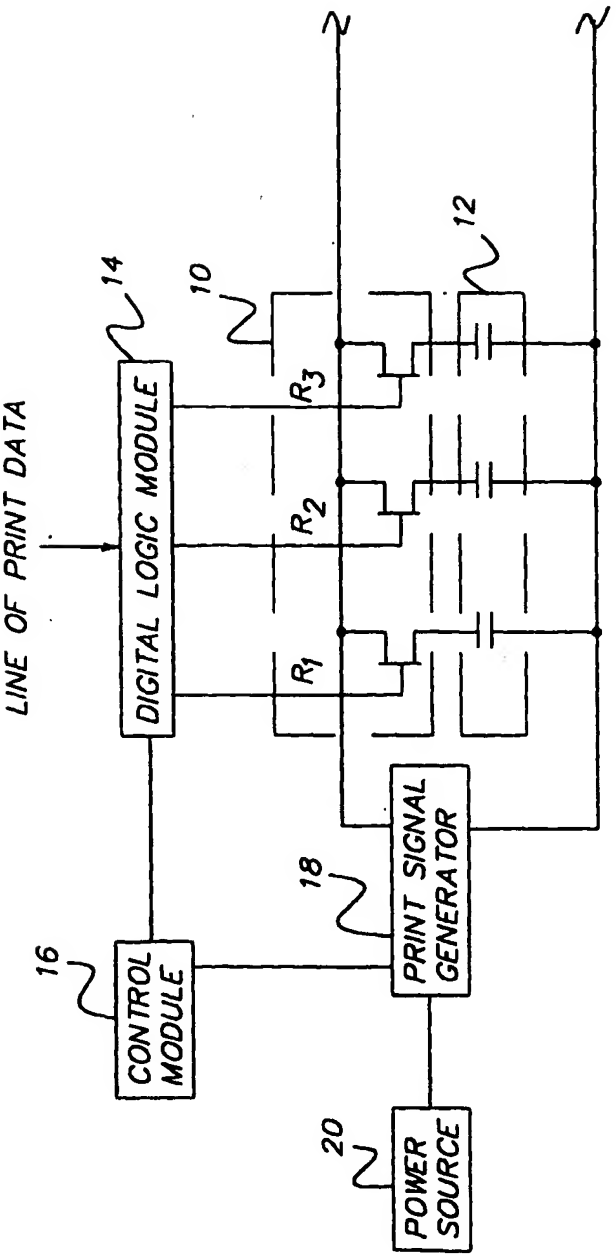
LINE OF PRINT DATA
DIGITAL LOGIC MODULE
14
10
12
R_3
R_2
R_1
CONTROL MODULE
16
PRINT SIGNAL GENERATOR
18
POWER SOURCE
20

FIG. 1

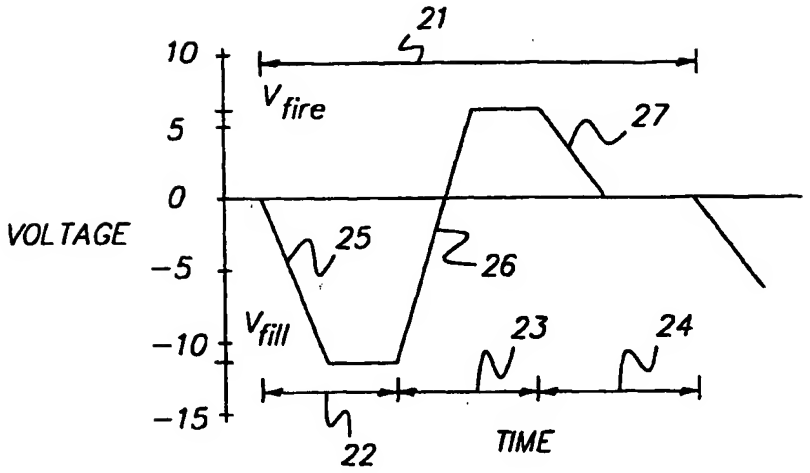

FIG. 2
(PRIOR ART)

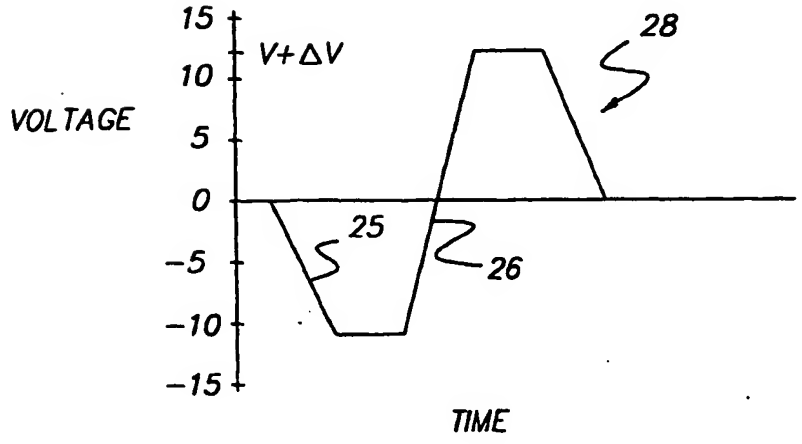

FIG. 3

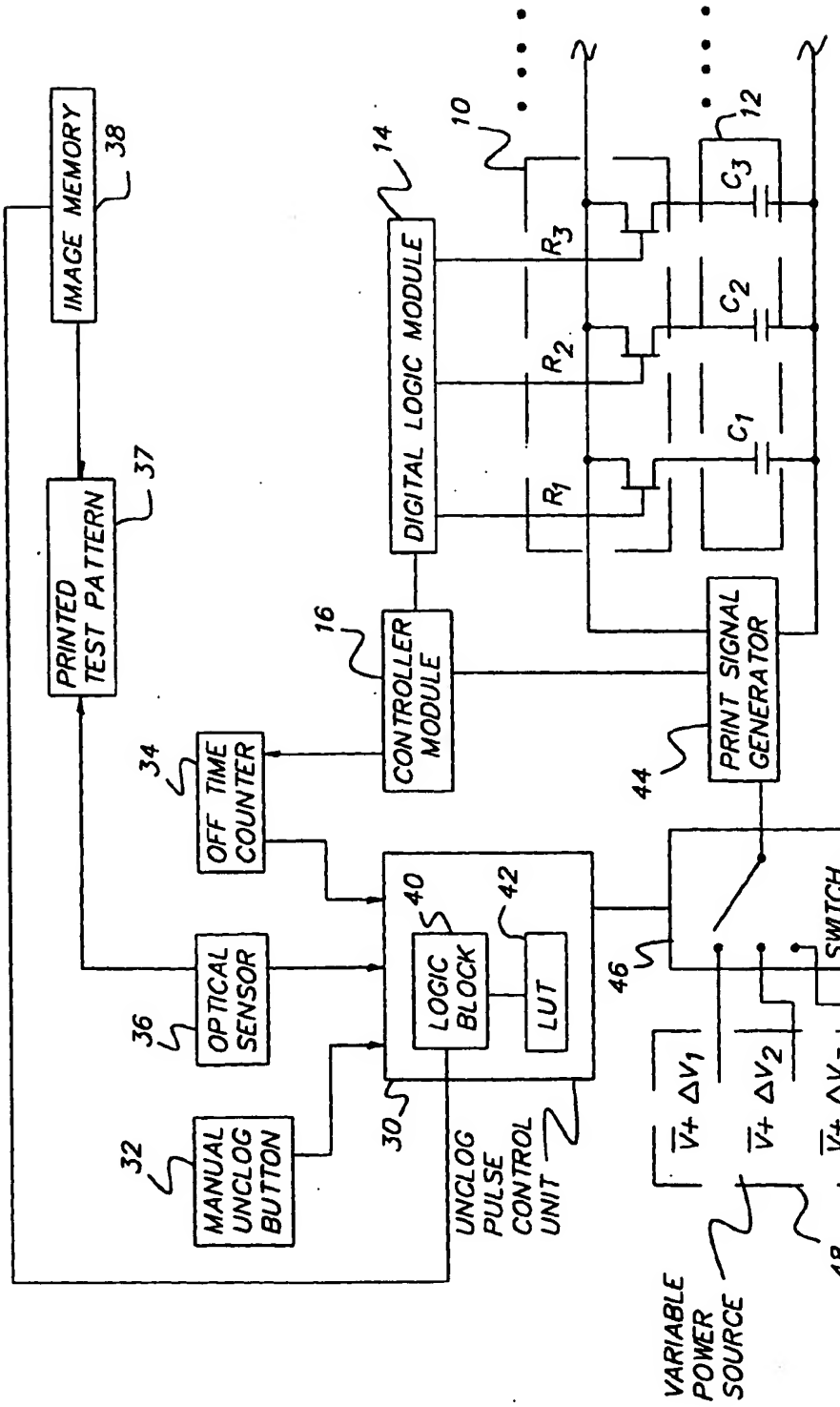
IMAGE MEMORY
38
PRINTED TEST PATTERN
37
DIGITAL LOGIC MODULE
14
10
12
R_3
R_2
R_1
C_3
C_2
C_1
16
CONTROLLER MODULE
34
OFF TIME COUNTER
PRINT SIGNAL GENERATOR
44
36
OPTICAL SENSOR
40
LOGIC BLOCK
42
LUT
46
SWITCH
32
MANUAL UNCLOG BUTTON
30
UNCLOG PULSE CONTROL UNIT
$\overline{V}+\Delta V_1$
$\overline{V}+\Delta V_2$
$\overline{V}+\Delta V_3$
VARIABLE POWER SOURCE
48

FIG. 4

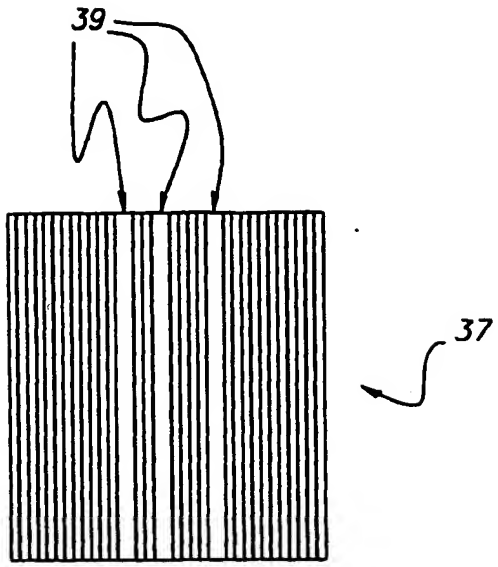

FIG. 5

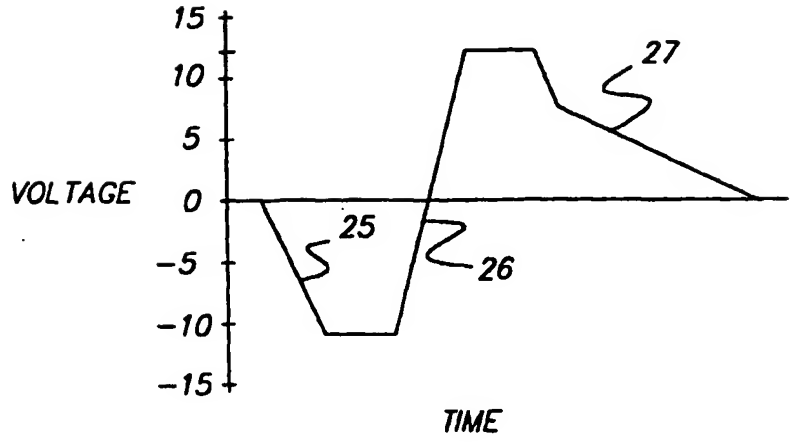

FIG. 7

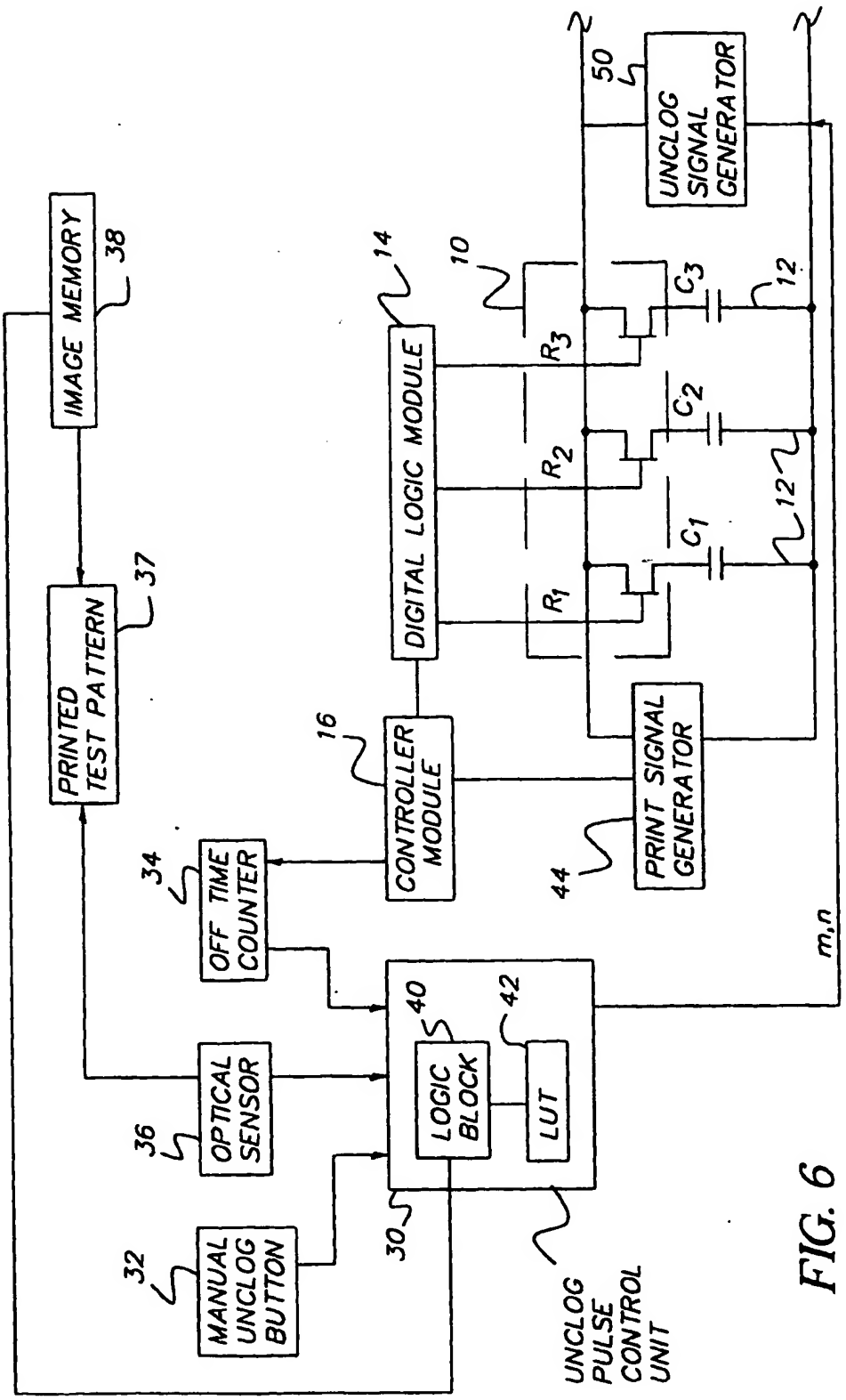
IMAGE MEMORY
38
PRINTED TEST PATTERN
37
DIGITAL LOGIC MODULE
14
10
R3
R2
R1
C3
C2
C1
12
12
50
UNCLOG SIGNAL GENERATOR
16
CONTROLLER MODULE
34
OFF TIME COUNTER
44
PRINT SIGNAL GENERATOR
m,n
40
LOGIC BLOCK
42
LUT
36
OPTICAL SENSOR
32
MANUAL UNCLOG BUTTON
30
UNCLOG PULSE CONTROL UNIT

FIG. 6

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EUROPEAN SEARCH REPORT

Application Number
EP 00 20 0824

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TECHNICAL FIELDS SEARCHED (Int.Cl.7)
B41J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 June 2000	De Groot, R

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29-06-2000

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